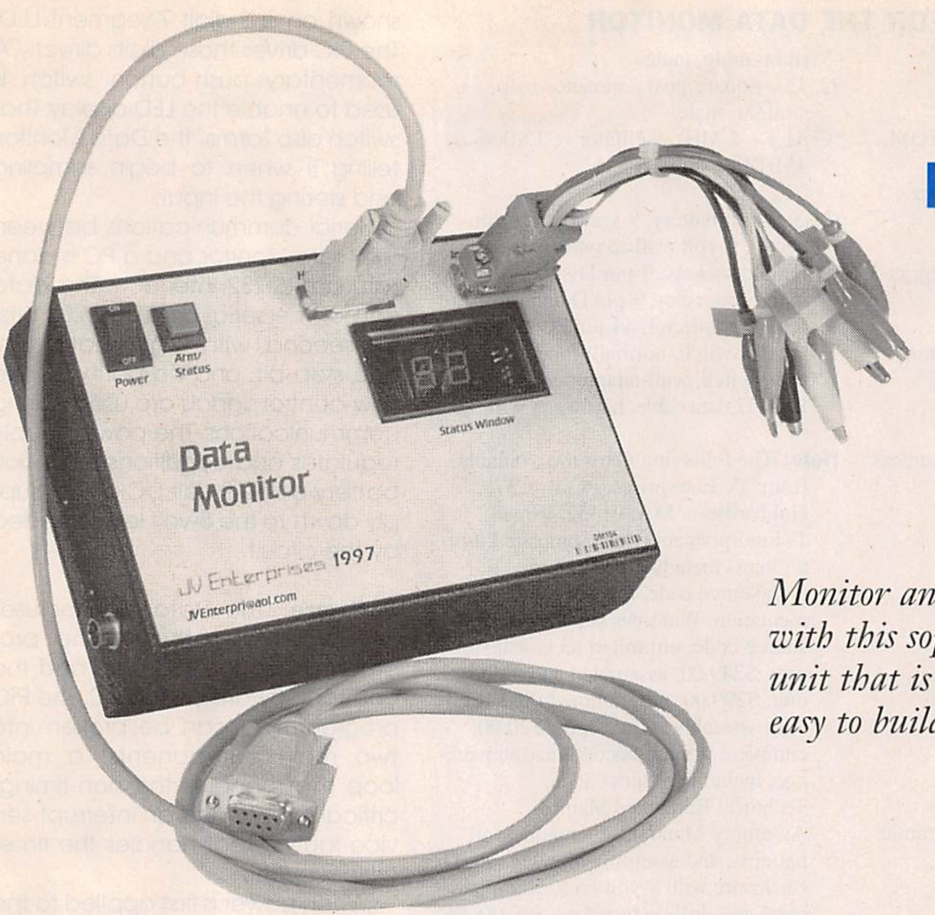


BUILD THE DATA MONITOR

Monitor and record events with this sophisticated unit that is both easy to build and use.

JON VARTERESIAN

Imagine how useful it would be to be able to monitor and record information about your environment for extended periods of time without having to be physically there. With a variety of input sensors, you could analyze the temperature of your attic to see if you really needed those ridge vents. You could count the number of people that came in and out of your store, and when each one entered and left, for weeks at a time. You could monitor the relative humidity or pressure of your lab or home. You could monitor the voltage and current output of your latest solar-cell project. You could even count the squirrels opening your squirrel feeder. The uses for such a monitoring device are only limited by the imagination. Now imagine how useful such a device would be if it could be run from either battery or AC power and didn't need to be tied to a PC to store information.

The Data Monitor described in this article is just such an instrument. It is highly configurable, low in cost, and easy to use. It can monitor and store up to four analog and four digital inputs at the same time. The sampling rate can be set anywhere from 30 milliseconds to more than 49 days. There is also an eight-term complex trigger that can include up to four digital and four analog inputs. All of the information is recorded in an electrically-erasable programmable read-only memory module (EEPROM) that has a capacity of 2048 words. The EEPROM is extremely error tolerant and can hold onto any data that has been stored in it even if the power is turned off or lost. Each sample has a time and date stamp included in order to protect the integrity of the data. That makes it easy to analyze any data that has been stored over a long period of time.

The Data Monitor is set up using an easy-to-use Windows-based program. Once it has been set up, the Data Monitor runs by itself. When the sample and store process is complete, the same program is then used to retrieve all of the data that has been collected. The only computer requirements for using the Data Monitor is a PC that is running either Windows 3.1 or Windows 95 and has an available COM1 or COM2 serial port.

The Data Monitor's hardware can monitor and record almost any electronic or electrical circuit through the use of plug-in personality modules. An accompanying article details the building of a general-puropse personality module that includes four digital and three analog inputs. Also included is a temperature sensor that uses the Data Monitor's fourth analog input. Although not needed to test the Data Monitor, building that personality module is a good idea and is very handy for testing the various functions of the Data Monitor.

How it Works. The heart of the Data Monitor is a PIC16C74 microcontroller, which controls all of the functions of the unit. That particular

PARTS LIST FOR THE DATA MONITOR

SEMICONDUCTORS

IC1—PIC16C74 microcontroller, programmed (Microchip)
IC2—24LC16B/P 16K serial EEPROM, integrated circuit (Microchip)
IC3—MAX232CPE RS-232 converter, integrated circuit (Maxim)
IC4, IC5—Not used
IC6—LM340T 5-volt regulator, integrated circuit
D1, D2—1N4001 silicon diode
Q1, Q2—FMMT3904 NPN transistor, SOT-23 package

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1, R3, R17–R20, R25, R26—10,000-ohm
R2—10-ohm
R4—not used
R5—12,100-ohm, 1%, metal-film
R6—4020-ohm, 1%, metal-film
R7, R8—not used
R9–16—91-ohm
R21–R24—not used

CAPACITORS

C1, C2—15-pF, axial ceramic
C3, C6, C7, C10—0.1-µF, axial ceramic
C4, C5, C8, C9—1-µF, 63-WVDC, electrolytic
C11—0.22-µF, axial ceramic
C12—10-µF, 25-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

DISP1—LN524 2-digit 7-segment light-emitting diode display, common cathode (Digi-Key P355-ND or similar)
J1, J4, J5—Square-post connector strip, right-angle, male
J2, J3—Square-post connector strip, straight, male
XTAL1—4-MHz oscillator (CTX006-4MHZ or similar)

Case, 9-volt battery, 9-volt battery connector, 9-volt wall adapter, square-post female sockets, 9-pin D-subminiature male, connector, 9-pin D-subminiature female connector, 44-pin PLCC socket, toggle switch, normally-open momentary switch, wall-adapter connector, RS-232 data cable, hardware, wire, etc.

Note: The following items are available from: JV Enterprises, PO Box 370, Hubbardston, MA, 01452. E-mail: JVEnterpri@aol.com: Complete kit of all items including programmed IC1 with source code, manuals and documentation, Windows software with source code, unlimited technical support, $249.00; assembled and tested unit, $299.00; programmed PIC16C74 with assembly source code, $20.00; complete printed documentation package, including Users Guide, Technical Reference Manual, Assembly Manual, schematics, foil patterns, and assembly drawing, $9.00; Enclosure with 9-volt battery compartment and drilling template, $20.00; PC board with silk-screen, plated holes, and solder mask, $13.50; Windows software with source code. $29.00. Please add $7.00 shipping and handling for complete kit and assembled unit; $5.00 for all other orders. Massachusetts residents must add 5% sales tax. Check or money order only.

member of the PIC microcontroller family has several features built into it that make it particularly attractive for use in the Data Monitor. Two of the features that help reduce the number of components in the circuit are a serial-interface controller and an 8-channel 8-bit analog-to-digital converter.

As mentioned above, analog and digital inputs are supplied to the unit through a plug-in "personality module." That module contains circuitry that can interface, buffer, or modify any input signals before they are passed to the Data Monitor itself. Although the design and construction of a personality module will not be discussed here, the article "Build this I/O-Temperature Personality Module" found elsewhere in this issue of **Electronics Now** describes a general-purpose personality module that will get you started with the Data Monitor. That add-on device will provide four digital inputs, three analog inputs, and one temperature-measurement input.

Data is stored and retrieved from the EEPROM using a two-wire technique called the *Inter-I* C (or IIC) protocol. That method was developed by Philips and Signetics. Although an "enhanced" specification that allows data transfers at a rate of 400,000 bits per second is supported by the EEPROM, the Data Monitor follows the 100,000 bits-per-second rate that was established by the original specification. See the sidebar for a technical overview of the IIC protocol.

Status for the Data Monitor is shown on a 2-digit 7-segment LED. The PIC drives those digits directly. A momentary push-button switch is used to enable the LED display. That switch also "arms" the Data Monitor, telling it when to begin sampling and storing the inputs.

Serial communications between the Data Monitor and a PC is done with an RS-232 interface. The data rate of the serial port is 19,200 bits-per-second with eight data bits, one stop bit, and no parity bit. No flow-control signals are used during communications. The power supply regulates and conditions the 9-volt battery or the 9-volt DC power supply down to the 5-volt level needed by the circuit.

Software. The Data Monitor uses two types of software: the programming in the PIC chip and the control software on the PC. The PIC programming can be broken into two main components: a main loop that handles the non-timing-critical events, and an interrupt-service routine that handles the time-critical events.

When power is first applied to the Data Monitor, the PIC program initializes all of its internal variables and waits for configuration information to be sent through the RS-232 port from the PC. While waiting, the Data Monitor's system voltage is monitored. That lets the battery voltage be checked at any time. Once the configuration data is sent to the Data Monitor, it is written to the EEPROM. When the arm switch is pressed, the Data Monitor begins sampling and storing data based on the user-supplied parameters. Once sampling has begun, the percentage that the EEPROM is full is also calculated. Any information that needs to be sent over the RS-232 link to the PC is also done.

The interrupt-service routine does two functions. The first function is to run the PIC's internal clock. Each "tick" of the clock is one millisecond. That means that anything that the interrupt-service routine is doing must be finished in less than one millisecond, or the next tick will be missed, messing up the Data Monitor's real-time clock. The other section services the RS-232's receive interrupt. That section takes care of all of the data that is received from the PC.

The Data Monitor is controlled by a Microsoft Windows program. With it, the Data Monitor is prepared for sampling, and the stored information is retrieved. When configuring the Data Monitor, you can say what combination of analog and digital inputs are to be stored, whether to average the analog samples or not, how many samples to include in any averaging, set the rate that the Data Monitor takes samples, what type of trigger mode to use, and define the eight-term trigger equation.

Most of the controls are self-explanatory. However, the trigger equation can become complex so some explanation is in order. Depending on your needs, the trigger equation can be used to set up any type of triggering condition from the very simple to the extremely complex. The format of the trigger equation is as follows:

(Trigger_1 & Trigger_2 & Trigger_3) # (Trigger_4 & Trigger_5 & Trigger_6) # (Trigger_7 & Trigger_8)

The "&" is a logical AND and the "#" is a logical OR. Each of the eight trigger terms can be linked to any one of the analog or digital inputs, along with one or more trigger modes. With a digital input, the trigger can become active when the input is rising, falling, or at the same level it was before the overall trig-

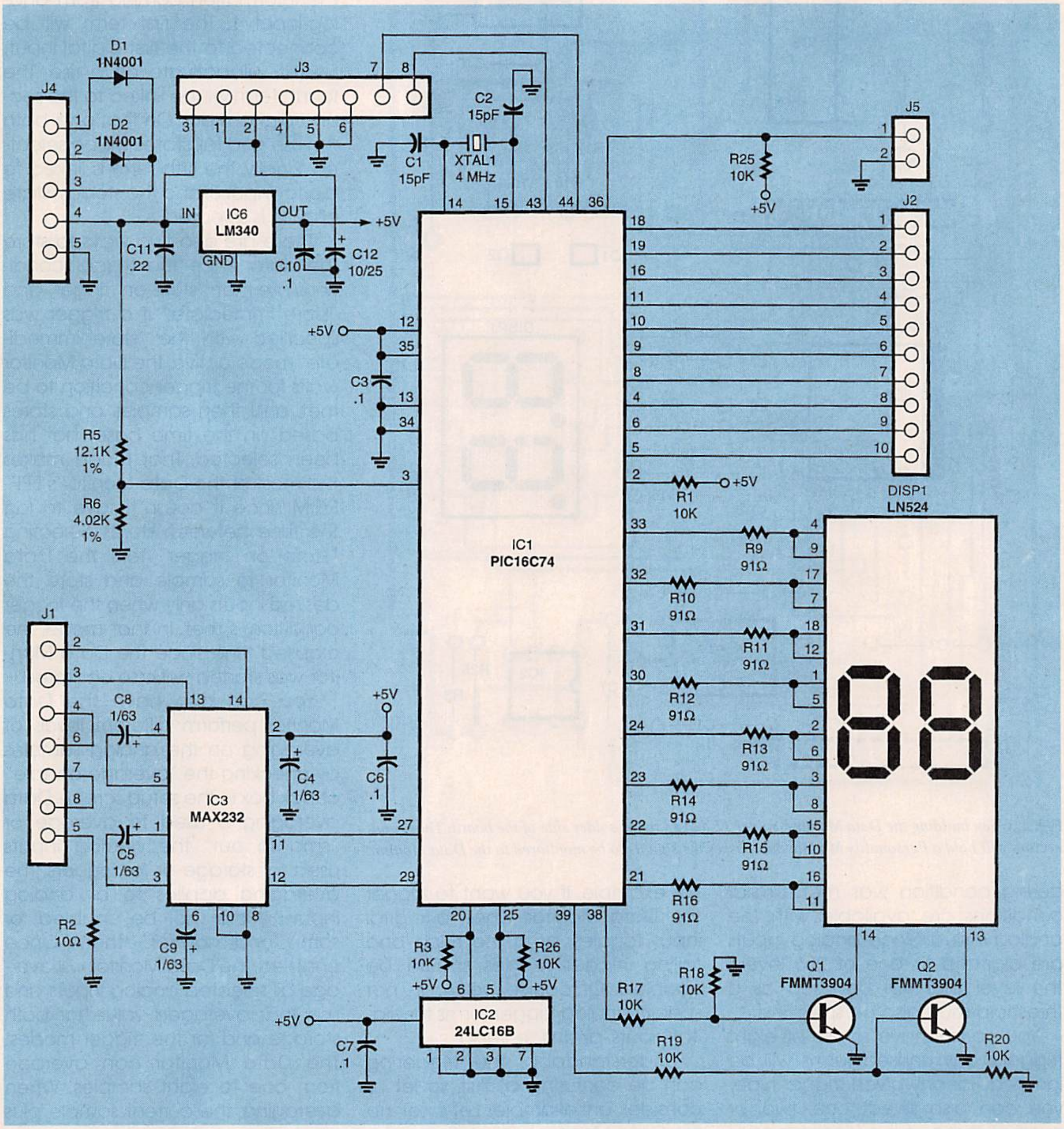


Fig. 1. The Data Monitor is built around a PIC16C74 microcontroller chip. It is easily powered by a wall transformer or a 9-volt battery.

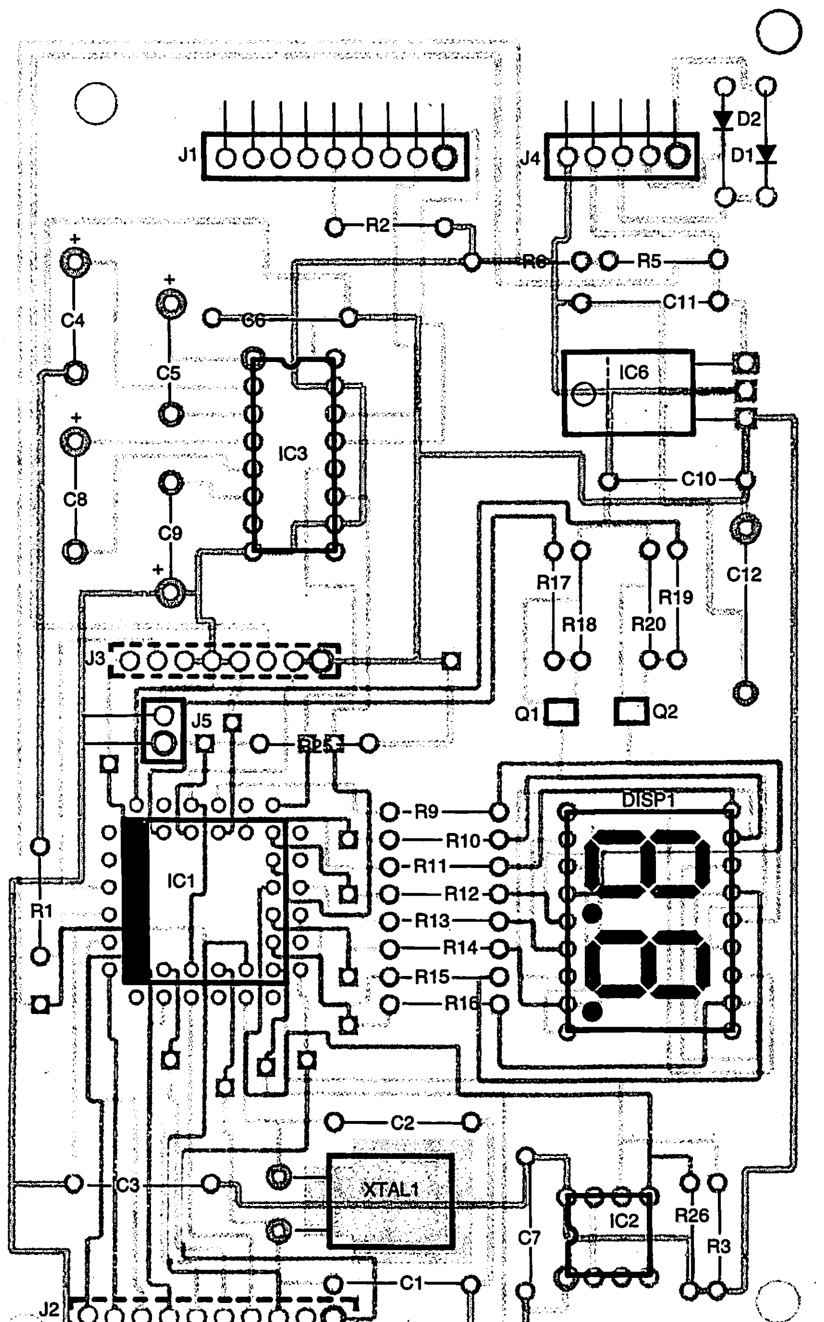


Fig. 2. When building the Data Monitor, solder J2 and J3 to the solder side of the board. Those connectors will hold a Personality Module that passes the signals to be monitored to the Data Monitor.

gering condition was met. Similar conditions are available with the analog inputs. Since analog inputs are digitized to one of 256 levels, the level that will be used as a threshold must also be specified.

You do not have to use all eight triggers; any unused terms will be ignored. For any given trigger type, you can also select one, two, or even all three of the trigger modes that are linked to a particular input. For example, if you want to trigger the Data Monitor when a digital input toggles, both the rising and falling trigger modes should be enabled. Of course, you can not specify analog trigger terms for digital inputs, and *vice versa.*

Understandably, the triggering can be confusing at first, so let us consider an example. Let's set up the Data Monitor to store the ambient temperature from a sensor connected to analog-input 1 whenever any of the following conditions are met: digital-input 1 rises or digital-input 2 toggles while digital-input 3 is high. We'll use trigger terms 1, 4, and 5. Remember, terms 1, 2, and 3 are linked together according to the logic formula given above. Similarly, terms 4, 5, and 6 are also linked together. Note that all other trigger terms are left unused so that they will be ignored.

The Data Monitor will only store the information coming from analog-input 1. The first term will be connected to the first digital input, and it will activate on a rise. The fourth term will be linked to the second digital input. On that one, both the rise and fall states will be selected. Finally, the fifth term is linked to digital-input 3, and the steady-state choice is selected.

There are also two ways to store the data once the trigger conditions are met: "store on trigger" and "store immediate." If a trigger was specified with the "store immediate" mode active, the Data Monitor waits for the trigger condition to be met, and then samples and stores based on the time base that has been selected. That mode makes the most of the Data Monitor's EEPROM since it doesn't have to log the time between stores. Selecting "store on trigger" tells the Data Monitor to sample and store the desired inputs only when the trigger condition is met. In that mode, the elapsed time since the Data Monitor was started will also be stored.

You can also have the Data Monitor perform different levels of averaging on the analog samples by checking the "average enable" check box in the setup screen. Data averaging is used to average or "smooth out" the analog inputs used for storage or for triggers. The averaging applies to all analog inputs; it can not be enabled for some and not for others. Once enabled, the Data Monitor will average all selected analog inputs and use that averaged value for both storage and for the trigger modes. The Data Monitor can average from one to eight samples. When averaging, the current sample plus the last several samples are used. For example, if eight samples are to

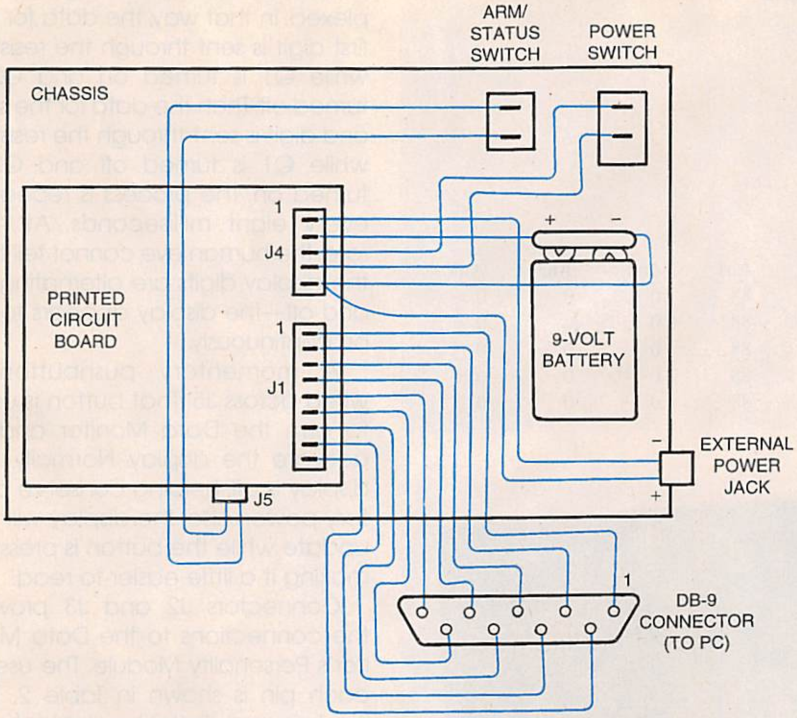


Fig. 3. Use extra care when wiring the Data Monitor's power connector. A mistake here can destroy the unit when power is applied.

TABLE 1

Sample No.	Input Value	Output (Averaging=2)	Output (No Averaging)
1	0	([0]+0)÷2=0	0
2	130	(0+130)÷2=65	130
3	128	(65+128)÷2=96	128
4	133	(96+133)÷2=114	133
5	130	(114+130)÷2=122	130
6	128	(122+128)÷2=125	128
7	128	(125+128)÷2=126	128
8	128	(126+128)÷2=127	128
9	128	(127+128)÷2=127	128
10	128	(127+128)÷2=127	128
11	128	(127+128)÷2=127	128

be averaged, the current sample plus the last seven samples are used. An example of the effects of averaging is shown in Table 1. In that example, an averaging of 2 is used to show the difference between averaging the data and storing the straight values.

Once all of the configuration information has been entered, the data is then sent to the Data Monitor over the RS-232 cable. Once that is done, the Data Monitor is then ready to be armed. It can be disconnected from the PC at this time and placed wherever it needs to be. Pressing the Arm/Status switch will arm the Data Monitor, and begin the sample and store process. You will see two three-bar characters on the display, showing that the sample and store process has begun. Pressing the Arm/Status switch will display the percentage that the EEPROM is full.

When the EEPROM is full, or you have collected enough data, you can download the information recorded in the Data Monitor to the PC for analysis. The same program is used to download the stored information. Type in the name of the file that you wish to save the data in and select a directory in which to store it. Press the OK button, and the software will download the collected data and place it in an ASCII text file with the name that you gave. The download process can take up to 5 seconds. The downloaded file can be opened by any standard text editor or word processor. You can also use a spreadsheet in order to analyze and chart the information from the Data Monitor.

Circuit Description. The schematic diagram in Fig. 1 shows that the Data Monitor is built around IC1, a PIC microcontroller. The circuit needs a DC power source between 7 and 12 volts that can supply 200 milliamps. That power is fed through J4. Both a 9-volt battery and a wall-mounted 9- to 12-volt DC adapter are connected through pins 1 and 2 of J4, with pin 5 serving as the ground. Each power source is isolated from each other by D1 and D2. The power is then routed through an on-off switch that is connected between pins 3 and 4 of J4. The power is regulated down to 5 volts by IC6 and filtered by C10–C12.

The rest of the circuitry supports IC1. Translating IC1's serial transmit and receive lines between TTL and RS-232 voltage levels is done by IC3. Through that chip and J1, the Data Monitor connects to a PC. The pinout on J1 is designed to match the pinout used on the 9-pin serial ports commonly found on PCs. An unusual feature of the serial-interface circuit is R2, which gives a small measure of short-circuit current protection for the RS-232 connection. Any power-supply noise that might disturb the operation of IC3 is decoupled by C6.

The Data Monitor's status is displayed on DISP1, a 2-digit 7-segment LED display. The display is a common-cathode type—all of the cathodes in each individual LED are tied together, with the anodes separated. The anodes of each digit are driven from IC1 directly through current-limiting resistors R9–R16. In order to minimize the number of pins needed for IC1 to control the dis-

LISTING 1

Data Monitor Download Data (V1.0) -- JV Enterprises

Storage Mode :: Immediate
Trigger Mode :: None
Average Off ::----
Time Stamp :: 20:50:22.070
Date Stamp :: 01\02\97
User Time Scale :: 30 MilliSeconds

Time	Dg1	Dg2	Dg3	Dg4	An1	An2	An3	An4
20:50:25.297	0	0	0	0	88	0	0	0
20:50:25.327	0	0	0	0	88	0	0	0
20:50:25.357	0	0	0	0	88	0	0	0
20:50:25.387	0	0	0	0	88	0	0	0
20:50:25.417	0	0	0	0	88	0	0	0

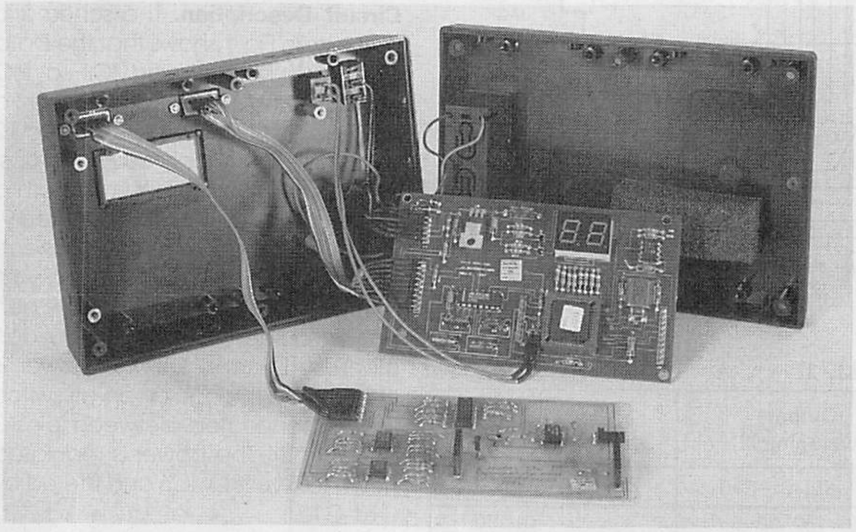


Fig. 4. When your Data Monitor is ready to be closed up, it should look something like this. The additional PC board in the foreground is a general-purpose I/O-temperature sensor Personality Module that is described in an accompanying article in this issue. You will need some type of Personality Module to use the Data Monitor. You can design your own if you want.

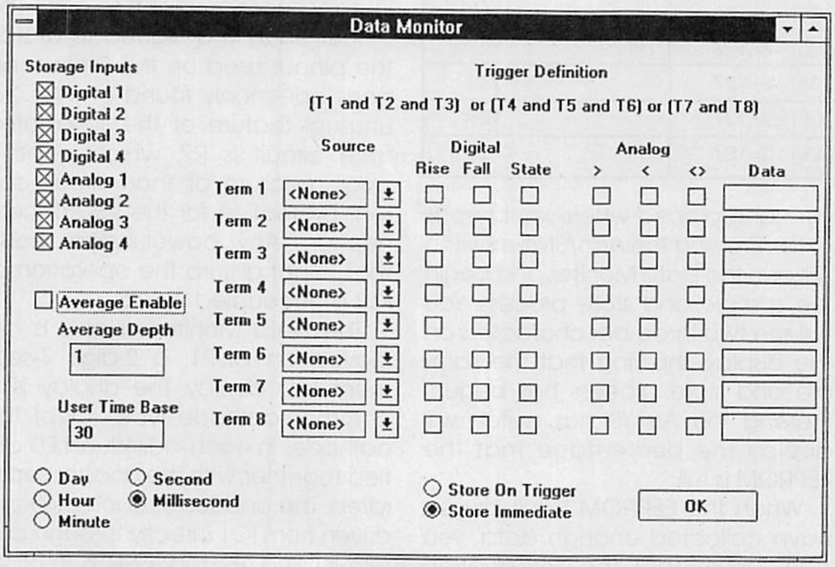


Fig. 5. Programming the Data Monitor is a snap with this Windows-based program. Selecting the various features and options is as easy as pointing and clicking with a mouse.

play, the data to each digit is multiplexed. In that way, the data for the first digit is sent through the resistors while Q1 is turned on and Q2 is turned off. Then the data for the second digit is sent through the resistors while Q1 is turned off and Q2 is turned on. The process is repeated every eight milliseconds. At that rate, the human eye cannot tell that the display digits are alternating on and off—the display appears to be on continuously.

A momentary pushbutton is wired across J5. That button is used to arm the Data Monitor and to activate the display. Normally, the display is off, helping conserve battery power. Also, the display will not update while the button is pressed, making it a little easier to read.

Connectors J2 and J3 provide the connections to the Data Monitor's Personality Module. The use of each pin is shown in Table 2. The analog- and digital-input signals are applied to those pins. The analog inputs are connected to the PIC's A/D converter. Two additional pins are used to let the Data Monitor know what type of Personality Module is connected to it. The voltage from a voltage divider made up of R5 and R6 is applied to one of the unused analog inputs of IC1. That way, the Data Monitor can also watch the unregulated voltage level of its own power supply, and take appropriate action if the batteries (if used) get too weak.

Building the Data Monitor. Although the Data Monitor is a sophisticated information-gathering device, its construction is quite straightforward. If you decide to etch and drill your own board, foil patterns are provided. As an alternative, an etched and drilled PC board can be purchased from the source given in the Parts List. Since the Data Monitor PC board is double-sided, you should make sure that all connections on both sides of the board are properly soldered if you make your own board. A purchased board will have all of the component and via holes plated, making assembly much easier.

Microcontroller IC1 must also be programmed with the instructions needed to run the Data Monitor.

Again, a pre-programmed part is available from the source given in the Parts List. Blank chips can also be programmed. The programming information, along with the computer-interface program, is available at the Gernsback FTP site (ftp://ftp.gernsback.com/pub/EN/datamon.zip).

Once you buy or etch your board, use the parts-placement diagram in Fig. 2 for the proper location of the components. Pay particular attention to the orientation of any polarized components. If a part is soldered onto the board backwards, removing it will be much more difficult due to the double-sided traces.

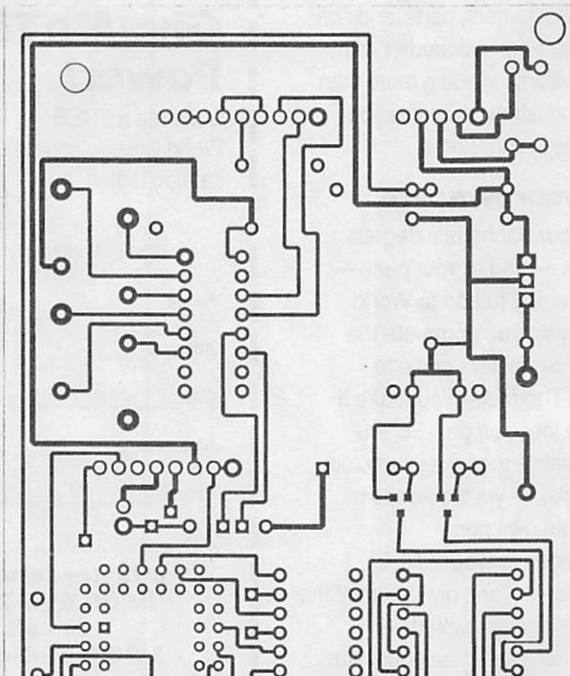
Start assembly by mounting all of the resistors and capacitors. A socket will also be needed for IC1. Sockets may also be used for the other ICs, but that is not necessary. Doing so, however, will make troubleshooting and repair of the Data Monitor much easier. Connectors J1–J5 should also be mounted. Note that J2 and J3 are mounted on the *solder* side of the board. The other connectors are right-angle types; their pins should point to the closest edge of the board.

The first semiconductor to be mounted is IC6. It should be mounted flat to the board with the metal tab facing *away* from the PC board and the plastic front *against* the board—opposite from the normal way to mount such a component. Before going any further, the board should be tested to see that the proper voltages appear at the various locations of the other semiconductors. If there is a problem or mistake in the board, it is easier (and less expensive) to correct the problem now rather than destroying several ICs. Set up a bench-type power supply for 9 volts DC. If you do not have a bench supply, a 9-volt battery can be used instead. Connect the positive terminal of the supply to pin 1 of J4 and the negative (ground) terminal of the supply to pin 5. The output voltage of IC6 should be 5 volts. That voltage should also appear at the several power-supply pins on the rest of the IC locations. Use the schematic diagram in Fig. 1 as a guide as to which pins should be checked. As a final test, pin 3 of IC1 should be about 3 volts. Once the board checks out, the rest of the semiconductors and DISP1 can be mounted. Double-check the orientation of the devices against Fig 2. as you mount them.

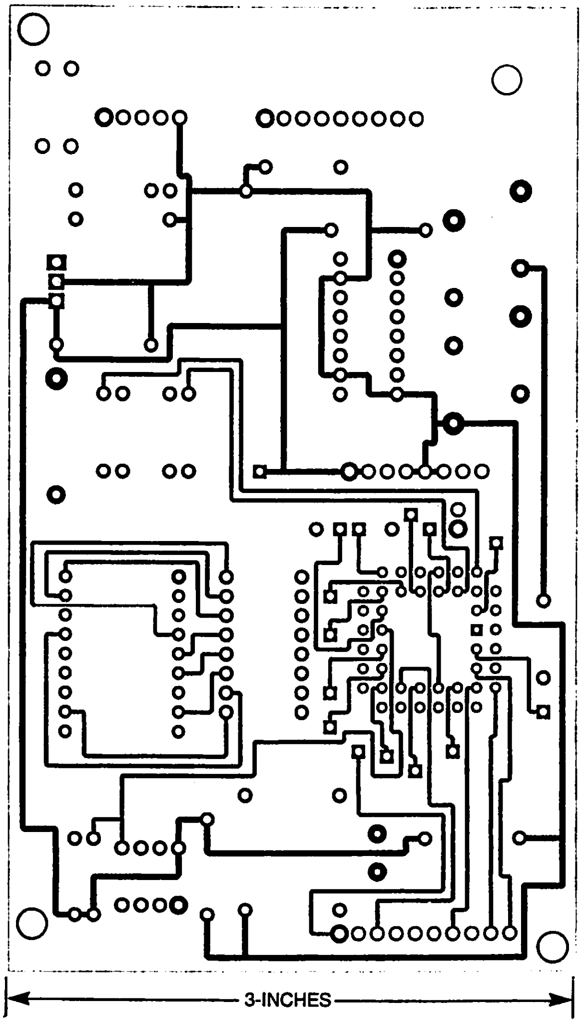
Prepare a suitably-sized enclosure by drilling and cutting holes for the power switch, status switch, and power connector. Four holes will be needed for mounting the PC board to the front panel. A cutout for viewing DISP1 is also needed in the front panel. In addition, two 9-pin connectors will be used for both the serial interface to the computer and to connect the monitored circuits to the Data Monitor's personality module.

The various connectors and switches are wired as shown in Fig. 3. Use suitable connectors for attaching the wires to J1, J4, and J5. The status switch simply connects across J5. The computer interface is wired to J1 connecting pin 1 to pin 1, pin 2 to pin 2, and so on. Pay special attention to the wiring of J4. That connector brings the 9-volt battery, the external DC wall adapter, and the Data Monitor's power switch together. Do not miswire J4, or the unit will be destroyed the first time power is applied. Wiring the input connector to the Personality Module will depend upon what type of connector and Personality Module you will be using.

Once all of the wires are attached to the various connectors, mount the connectors and switches to the enclosure. Attach the connectors at the other ends of the wires to J1, J4, and J5. If you are using the Personality Module described in the accompanying article, the unit should look similar to Fig. 4. Simply



Here is the foil pattern for the component side of the Data Monitor PC board.



Here is the foil pattern for the solder side of the Data Monitor PC board. If you etch and drill your own board, don't forget to connect any foil connections that pass from one side of the board to the other.

TABLE 2

PINOUT FOR J2	
Pin No.	**Signal**
1	Digital Input 1
2	Digital Input 2
3	Power On/Off Control
4	Personality ID 2
5	Personality ID1
6	Personality 0
7	Analog Input 4
8	Analog Input 3
9	Analog Input 2
10	Analog Input 1
PINOUT FOR J3	
Pin No.	**Signal**
1	5-volt regulated supply
2	5-volt regulated supply
3	9-volt unregulated supply
4	Ground
5	Ground
6	Ground
7	Digital Input 4
8	Digital Input 3

screw the PC board onto the spacers mounted on the front panel, mount the Personality Module onto J2 and J3, and close up the case. The Data Monitor is now ready for testing.

Testing. Now that you have fully completed assembling the Data Monitor, you must test it to make sure it is fully functional. Insert a fresh 9-volt battery or attach a 9-volt DC wall adapter to the Data Monitor. Turn on the power switch and press the Arm/Status button. Two single bars should be seen in DISP1. That means that the Data Monitor is ready for communications with the host computer.

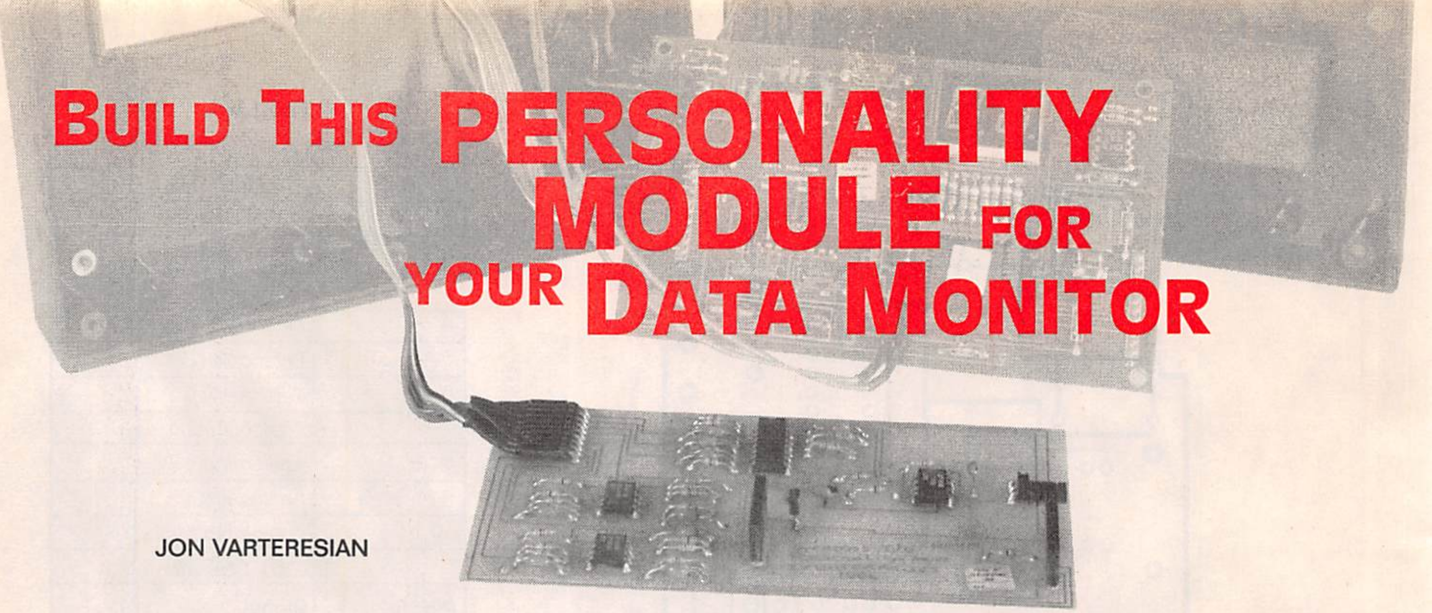
Connect the serial cable from the Data Monitor to the PC and run the Data Monitor software. Click on the "Configure" pull-down menu and select "Comport." Choose the serial port that the Data Monitor is attached to. Now select "Setup" from the "Configure" pull-down menu and set the Data Monitor's options to record all of the digital and analog inputs. You can leave all other options at their defaults. With the Data Monitor storing information at 30-millisecond intervals, the setup screen should look like the example shown in Fig. 5.

Send the setup information to the Data Monitor by selecting "Initialize" from the "Configure" pull-down menu. You should see a "Data Monitor Initialized" information box if everything went OK. If not, check both the internal and external cables and connections. Make sure that you haven't plugged some of the internal cables on backwards.

Now press and hold the Arm/Status button. You should see two three-bar characters on DISP1. Release the button. The Data Monitor is now sampling and storing the data from the analog and digital inputs. The complete cycle should take less than a minute. Let the Data Monitor run until it is full. You can check on the progress of the cycle by pressing the Arm/Status button. When pressed, DISP1 will display how full the EEPROM is as a percentage. The status will not update while you hold the button. To update the display, let go of the button and press it again. When the status window shows "00.," the Data Monitor is finished and ready for downloading to the host. The dot to the right of the zeros shows that the Data Monitor is full. You do not need to wait for the EEPROM to fill completely before downloading; you can download at any time.

Select the "Download" pull-down menu and pick "Download." A pop-up menu will appear. Choose a directory and filename for the downloaded data. Press the "OK" button, and the software will download the Data Monitor and place the data in a text format in the loca-

(Continued on page 48)



BUILD THIS PERSONALITY MODULE FOR YOUR DATA MONITOR

JON VARTERESIAN

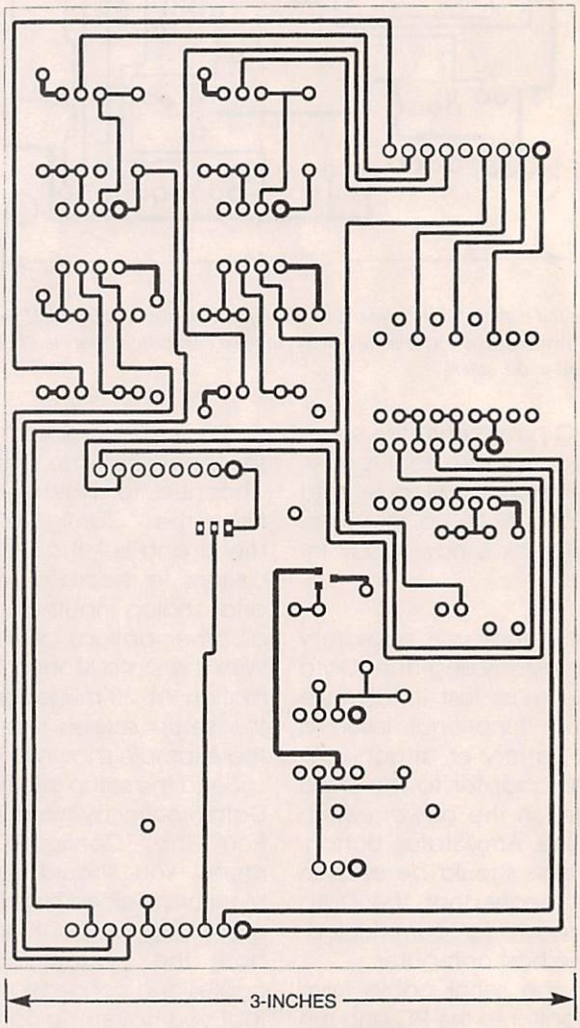
A Personality Module for the Data Monitor will get you started with monitoring digital and analog inputs. You can even track the temperature at the same time!

By now, you've probably studied the Data Monitor described elsewhere in this issue. You probably have some ideas as to where such a useful device can be used. You're ready to roll up your sleeves and dive right into the construction, but that article says that you need a Personality Module to connect the Data Monitor to the outside world. You might not have the patience or expertise to design your own, but you'd still like to use the Data Monitor. It seems like you'll never be able to use the Data Monitor.

Enter the General-Purpose I/O-Temperature Personality Module! This add-in circuit board for the Data Monitor will let you get started with using the Data Monitor, and just might be all that you need for all of your data sampling and event recording.

How it Works. In order to use different sensors for unique monitoring applications as well as to protect the internal circuitry from surges and possible electrical damage, the Data Monitor is designed to use what is called a Personality Module. A Personality Module connects to the Data Monitor's main circuit board through a 10-pin and an 8-pin connector.

This Personality Module is a very simple design. It has buffer circuits



Here is the foil pattern for the component side of the Personality Module.

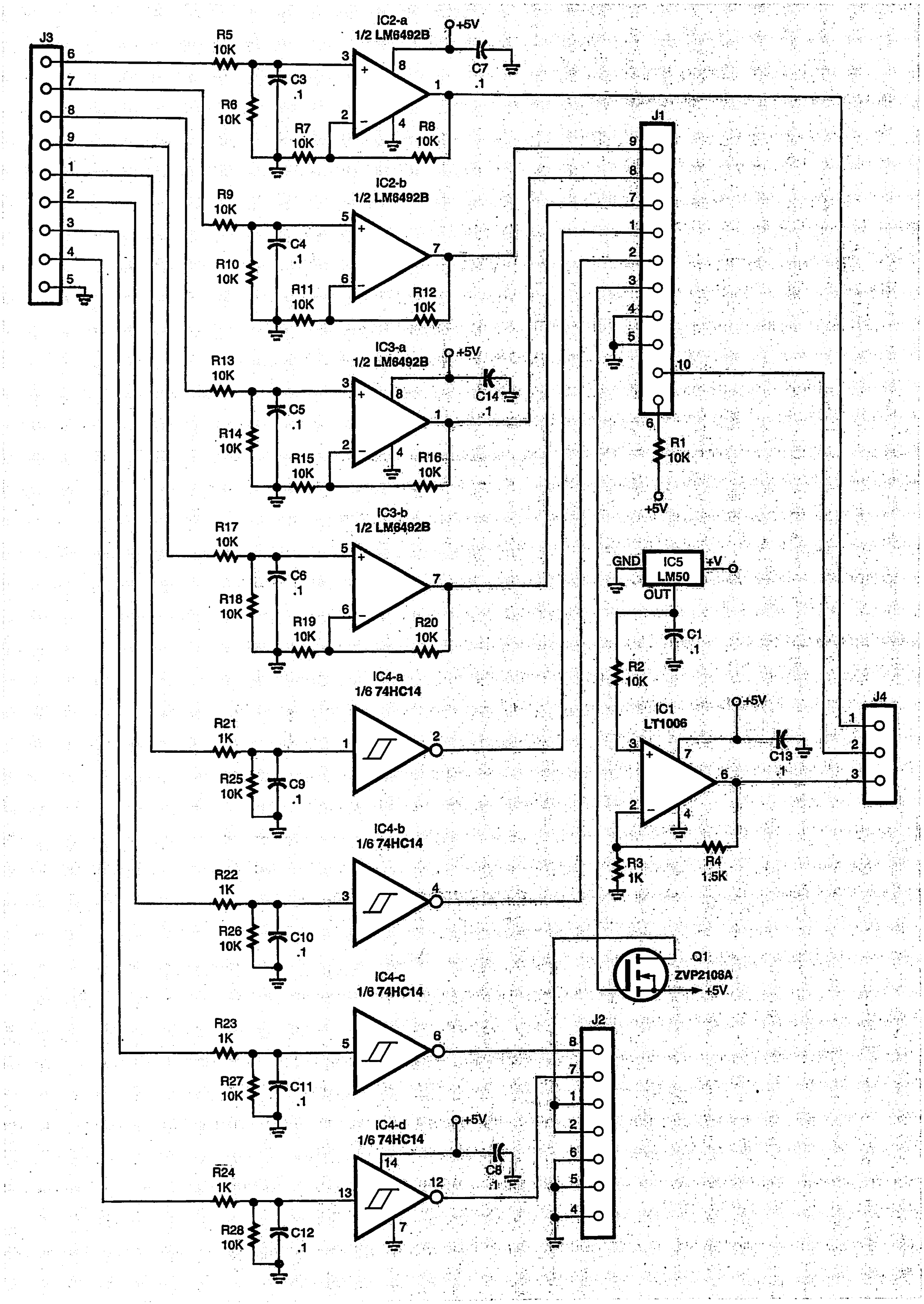


Fig. 1. The Personality Module is a set of simple analog and digital buffers that protect the Data Monitor's sensitive circuitry. Analog-input 1 can also be used to measure temperature.

for both the digital and analog inputs, as well as an on-board temperature sensor. The temperature sensor is designed to connect to the Data Monitor through analog-input 1. If you need all four analog inputs, or you just need to use the first analog input for whatever reason, a movable jumper block on the Personality Module lets you bypass the output of the temperature sensor. That way, the first analog input has the same buffering circuit that the other analog inputs have.

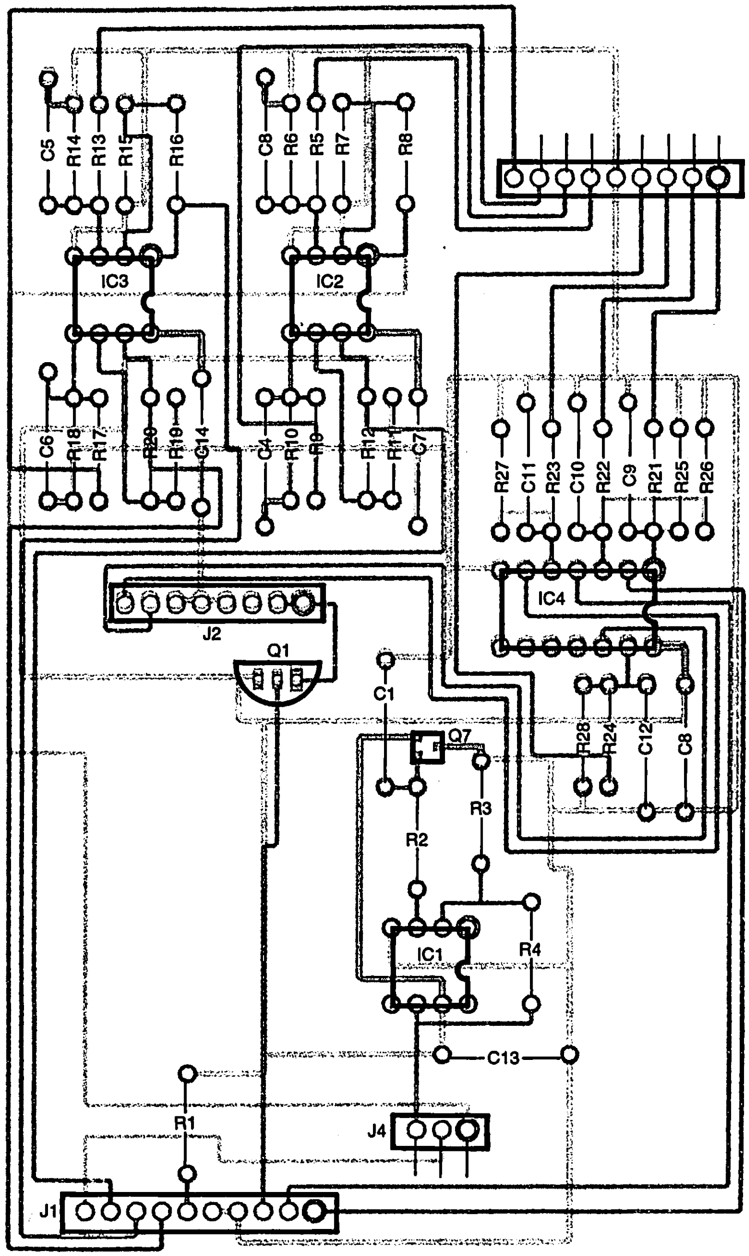


Fig. 2. When building the Personality Module, be careful of the orientation of the polarized parts. Some of the semiconductors are sensitive to ESD, especially Q1.

Power for the Personality Module comes from the Data Monitor itself. An on-off control transistor is included for future compatibility; future versions of the Data Monitor software will let the Data Monitor power down the Personality Module circuitry in order to conserve battery power if the Data Monitor is going to be used in the field where a wall adapter cannot be used for extended periods of time.

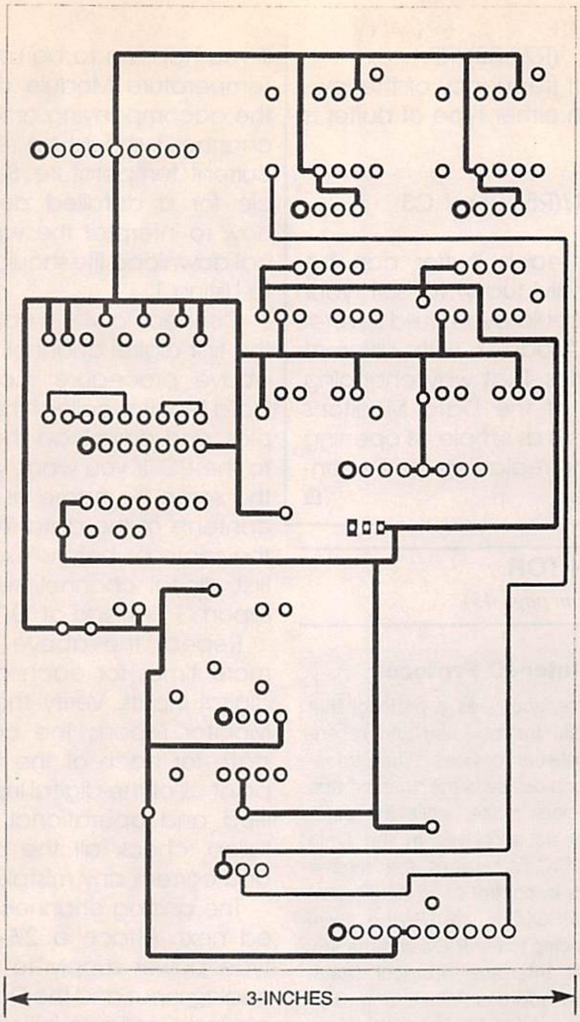
Circuit Description. The schematic diagram for the General-Purpose I/O-Temperature Personality Module is shown in Fig. 1. The buffering circuits for the digital and analog inputs are the same buffer circuit duplicated for each channel. Only one of each type of channel will be described. The other three channels of each type will work the same way.

In the analog channel, the input signal is buffered by IC2-a, an LM6492 CMOS rail-to-rail op-amp. Resistors R5 and R6 form a voltage divider on the input signal. With a value of 10,000 ohms, the input signal is attenuated by a factor of 2 for a gain of ½. Those values also present an input impedance of about 20,000 ohms to the source of the signal. The op-amp is used as a non-inverting voltage follower. The gain of IC2-a is set by R7 and R8. With those resistors at 10,000 ohms, IC2-a has a gain of 2. Capacitor C3 along with R5 and R6 form a low-pass filter that has a cutoff frequency of about 500 Hz with the values shown. A gain of ½ followed by a gain of 2 will have an effective gain of 1 for the analog buffer circuit.

The digital buffer is built around IC4, a 74HC14 inverting Schmitt trigger. Using a Schmitt trigger helps clean up any slow-rising digital signals and prevents any jitters if the input does not change cleanly from one state to the other. A low-pass filter is formed by R21, R25, and C9. With the values shown, the cutoff frequency is about 910 Hz. Resistor R25 does extra duty by holding a valid logic level on the inputs of IC4-a if the input is not being used. Without it, the input of IC4-a will act like an antenna, picking up stray noise that will cause problems with the other gates in IC4. The input impedance that the external digital signals will see from the input buffer is about 11,000 ohms.

Temperature sensing is done by IC5, a National Semiconductor LM50. That sensor is capable of detecting temperatures between −10 and +50°C. It has a very linear output over the full range of temperatures. The output voltage of the LM50 for any particular temperature can be found by using the formula:

Output Voltage=0.5 volts+(0.01 volts × °C)



Here is the foil pattern for the solder side of the Personality Module.

For example, a temperature of 20° C would yield an output voltage of 0.5 + (.01×20), or 0.7 volts.

The output of the temperature sensor is then amplified by IC1, a non-inverting op-amp with a gain of 2.5. That gain increases the voltage range of IC5 so that it will cover the full range of the Data Monitor's analog-to-digital converter. The reference voltage for the A/D converter inside the Data Monitor is 5.0 volts. Since the converter is an 8-bit device, the digital value reported by the Data Monitor is represented by the following formula:

Reported value=(Input voltage/5) × 255

A temperature of 20° C produces an output of 0.7 x 2.5, or 1.75 volts. The Data Monitor's A/D converter would output a value of 89.

The input to the first analog input can be switched between the temperature sensor and the usual analog input voltage by shorting the appropriate pins on J4 with a jumper block. With the jumper in place between pins 1 and 2, analog input will be routed to the Data Monitor. If you want to read the temperature sensor, place the jumper on pins 2 and 3.

The Personality Module also contains Q1, a P-channel MOSFET, in order to control the power consumed by the Personality Module. The current version of the Data Monitor PIC program leaves Q1 always on, so that the Personality Module is always powered up. As previously mentioned, future versions of the Data Monitor software will be able to turn the Personality Module on only when data sampling is to take place. That technique will help conserve power when the unit is operating from a 9-volt battery.

Connections for the digital and analog inputs are made through J3, with J1 and J2 being used to mount the Personality Module onto the back of the Data Monitor's main board.

Building the Personality Module. The Personality Module is a simple double-sided PC board. Foil patterns are included if you wish to etch and drill your own board. As an alternative, you can purchase one from the source given in the Parts List. In either case, the parts-placement diagram in Fig. 2 shows where the various components are to be located.

All of the components are located on the component side of the board. If you are using a board that you etched yourself, keep in mind that you will have to solder connections on both sides of the board if you did not plate the holes beforehand. It is easiest to begin by mounting the smallest parts first. Start with the resistors and capacitors. Follow them with the connectors. Once all of the passive components have been soldered to the board, install the ICs. The temperature sensor, IC5, should be the second-to-last component installed. Finish the board by installing Q1. Be careful when installing Q1, as it is very sensitive to electrostatic discharge. The jumper on J4 should be installed depending on whether you want to use the Personality Module's temperature-sensing capability. Placing the jumper on pins 2 and 3 of J4 will select the on-board temperature sensor.

When the Personality Module is finished, inspect it carefully for poor solder joints, solder bridges, incorrectly-installed components, and other similar errors in workmanship. Once you are satisfied with your work, the Personality Module can be installed in the Data Monitor by simply inserting J2 and J3 into the connectors on the back of the Data Monitor's main board.

If you want, you can mount an additional 9-pin connector onto the Data Monitor's case and connect it to J3 of the Personality Module. That way, you will have a convenient way to connect the Data Monitor to whatever devices you wish to monitor. You may use any pin numbers

PARTS LIST FOR THE GENERAL I/O - TEMPERATURE MODULE

SEMICONDUCTORS

IC1—LT1006CN8 op-amp, integrated circuit (Linear Technologies)
IC2, IC3—LM6492BEN op-amp, rail-to-rail, integrated circuit
IC4—74HC14 hex Schmitt trigger, integrated circuit
IC5—LM50 temperature sensor, integrated circuit (National Semiconductor)
Q1—ZVP2106A P-channel MOSFET transistor (Zetex)

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1, R2, R5–R20, R25–R28—10,000-ohm
R3, R21–R24—1000-ohm
R4—1500-ohm

ADDITIONAL PARTS AND MATERIALS

C1, C3–C14—0.1-mF, axial-ceramic capacitor
C2—Not used
J1, J2—Square-post connector, straight, female
J3, J4—Square-post connector, right angle, male
Jumper block, hardware, etc.

Note: The following item is available from: JV Enterprises, PO Box 370, Hubbardston, MA, 01452. E-mail: JVEnterpri@aol.com: PC board with silk-screen, plated holes, and solder mask, $13.50. Please add $5.00 shipping and handling. Massachusetts residents must add 5% sales tax. Check or money order only.

you wish for the 9-pin connector; just make a careful note of which pins are connected to which input channels. If you are going to use the temperature sensor, you should drill several holes in the Data Monitor's case so that the air around the Data Monitor will be able to reach IC5.

Circuit Modifications. You can change the values of the resistors on the input-buffer circuits if you need different levels of amplification or attenuation. On the analog input circuit, the gain of the input resistors is:

$$R5/(R5+R6)$$

The overall gain of the buffer is the resistor gain times the op-amp gain. To adjust the op-amp gain, use the following formula:

$$(R7+R8)/R7$$

The cutoff frequency of the low-pass filter on either type of buffer is found by:

$$1/(R5+R6) \times C3$$

Naturally, each buffer can be modified individually to suit your needs. You could even build several Personality Modules with different characteristics. That way, changing the design of the Data Monitor's input circuits is as simple as opening the case and replacing the Personality Module. Ω

DATA MONITOR

(continued from page 43)

The Inter-IC Protocol

The IIC interface uses a protocol that ensures reliable transmission and reception of data between devices. When transmitting data, one device is the "master" that generates a clock pulse, while the other device(s) acts as a "slave." In the Data Monitor, the PIC is always the master device, always in control of all data transfers. The EEPROM is always the slave device, responding to the PIC's commands.

In the IIC interface protocol, each device has an address. When a master wishes to start a data transfer, it first transmits the address of the device that it wants to "talk" to. All of the devices on the IIC bus listen to see if the address being sent is their address; only the target device responds. Within the address field, one bit specifies whether the master wishes to read or write to the target device. In the Data Monitor, IC2 (the EEPROM) has a fixed constant in the address field because it is the only slave device on the IIC interface bus, so it does not need an address. In any case, the master device generates the clock for the data transfer. In the Data Monitor, the clock is transmitted on pin 20 of IC1, and the data is transmitted and received on pin 25. For more detailed information, Microchip's databooks are excellent sources for their devices (the PIC and the EEPROM). The original specification from Philips and Signetics, "The IIC Bus and How to Use It" is also an excellent source of information.

tion and under the name that you chose.

Open the download file with any text-viewing program. Because all of the Data Monitors inputs were left unconnected, all of the digital and analog inputs should report "0." If you happen to be using the I/O-Temperature Module described in the accompanying article, analog-channel 1 should be reporting the current temperature. See that article for a detailed description of how to interpret the values. A typical download file should look similar to Listing 1.

Connect a 4½–5-volt source to the first digital channel. Repeat the above procedure: configure the Data Monitor, collect the data samples, and download the new data to the PC. If you want, you can use the same file name as before. The contents of the data file should be the same as before except for the first digital channel, which should report "1" instead of "0."

Repeat the above steps three more times for each of the other digital inputs. Verify that the Data Monitor reports the correct logic state for each of the tests. At this point all of the digital inputs are verified and operational. If any test failed, check all the connections and correct any mistakes.

The analog channels will be tested next. Attach a 2½-volt bench-type power supply to the second analog input and the Data Monitor's ground. Configure, initialize, arm, and download information from the Data Monitor as before. You should see that the second analog channel has a value of about 128±1. As with the digital channels, test each analog channel in the same way.

The Data Monitor is now fully operational and needs only the addition of a personality module to be ready for use. Details on a suitable module can be found beginning on page 44. Congratulations and happy monitoring! Ω